



UNIVERSITY OF GOTHENBURG

An Evaluation of Voice Recognition Approach for Technical Support at Volvo

Master of Science Thesis in Software
Engineering and Management

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Voice Recognition Approach for Technical Support at Volvo

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Abstract

This exploratory case study presents the results of using a mobile-based Automated Speech Recognition solution in noisy environment to improve the usability of an IT system. Interviews, observations and qualitative analysis were made to identify the constraints/problems. A mobile-based Automated Speech Recognition prototype was developed and its evaluation was performed through end user in noisy condition. The study results showed such an approach does not help in improving the usability of the IT system due to Automatic Speech Recognition's speech to text in accuracy and the user's reluctance to speak without system response.

1. Introduction

Among the tasks for which machines may simulate human behavior, automatic speech recognition (ASR) has been foremost since the advent of computers [1]. It's capability as an alternate way for human computer interaction has enabled remarkable progress in this field from dictation based software like *IBM's ViaVoice*¹ to speech based personal assistant like Apple's *SIRI*².

To understand the capabilities of an ASR as an alternate form of human-computer interaction, an exploratory case study was conducted with Volvo Information Technology AB³ in Gothenburg, Sweden. The study consisted of investigating problems in typed text approach for reporting cases in Argus system for Volvo aftermarket and how an ASR can be used to create cases in Argus system to improve quality of reported cases in a noisy environment.

The case study is organized as with section 1 giving a theoretical background of the ASR technology, it's limitations/challenges, what is the state of the art in this area & it's related works. Section 2 presents the actual case study conducted, the problem addressed and the adopted research methodology. Section 3 presents prototype experiment, workshop session and user feedback. Section 4 presents results from section 3. Section 5 presents the theory/interpretation of the study and finally section 6 presents discussion on the study with future approach.

2. Background

2.1. Automatic Speech Recognition (ASR)

According to Jurafsky and Martin [2], speech recognition systems enable machines to understand and process human voice commands to achieve a result, a more technical definition by Jurafsky and Martin [2] is "the building of system for mapping acoustic signals to a string of words" further they describe the purpose as "the goal of this new field is to get computers to perform useful tasks involving human language[...] or useful processing of text or speech".

¹ <http://www-01.ibm.com/software/pervasive/viavoice.html>

² <http://www.apple.com/ios/siri/>

³ www.volvokit.com

Figure 1 shows a typical Speech recognition systems, it consists of:

- Signal Processing
- Language Model
- Acoustic Model
- Speech Recogniton Engine

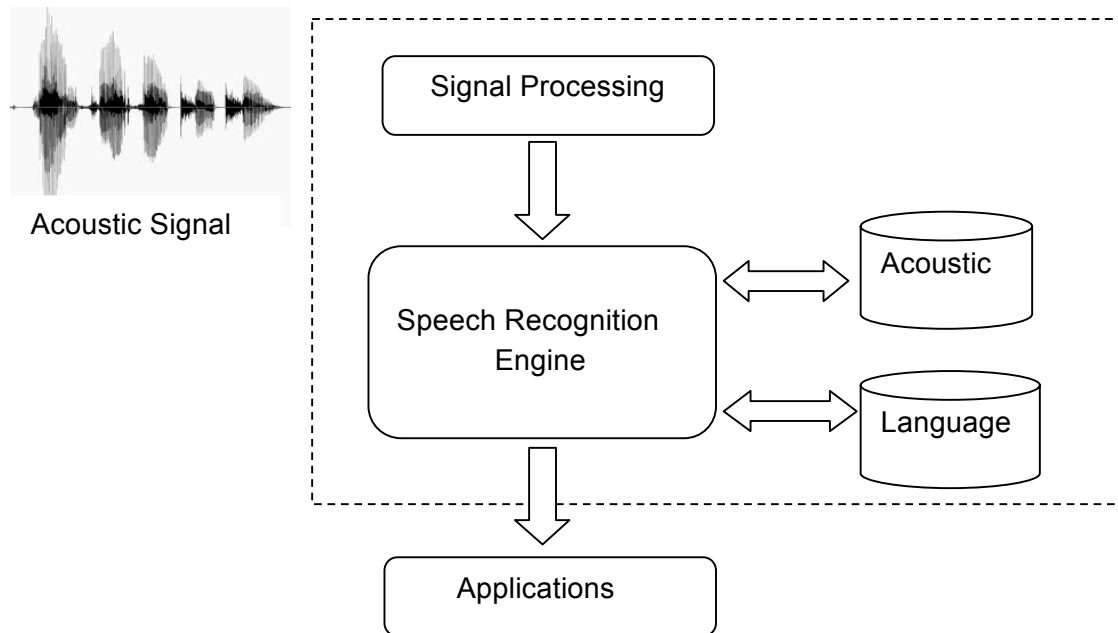


Figure 1 Basic Architecture of Speech Recognition System [3]

The **Signal Processing** component converts the analog signal to a digital signal and removes noise from the signal. The **Speech Recognition Engine** processes the input signal by consulting with **Acoustic Model** which is a database containing information about phonetics and speaker variability and **Language Model** which is a database of words, finally it outputs the results to any interfacing application.

2.2. Performance and Challenges

According to Deng and Huang [4], SR has made a dramatic progress over the past 30 years triggered by advances in computing devices and architectures, success of algorithm development and availability of large quantities of data. However, reducing the SR error rate remains greatest challenge in making it more mainstream [4]. Figure 2 gives an idea of the reduction of word error rate over the passage of time in relation to vocabulary size and type speech SR can support. According to Jurafsky and Martin [2], **word error** rate is standard evaluation metric for SR systems and is based on how much word string returned by the recognizer differs from the correct or reference transcript.

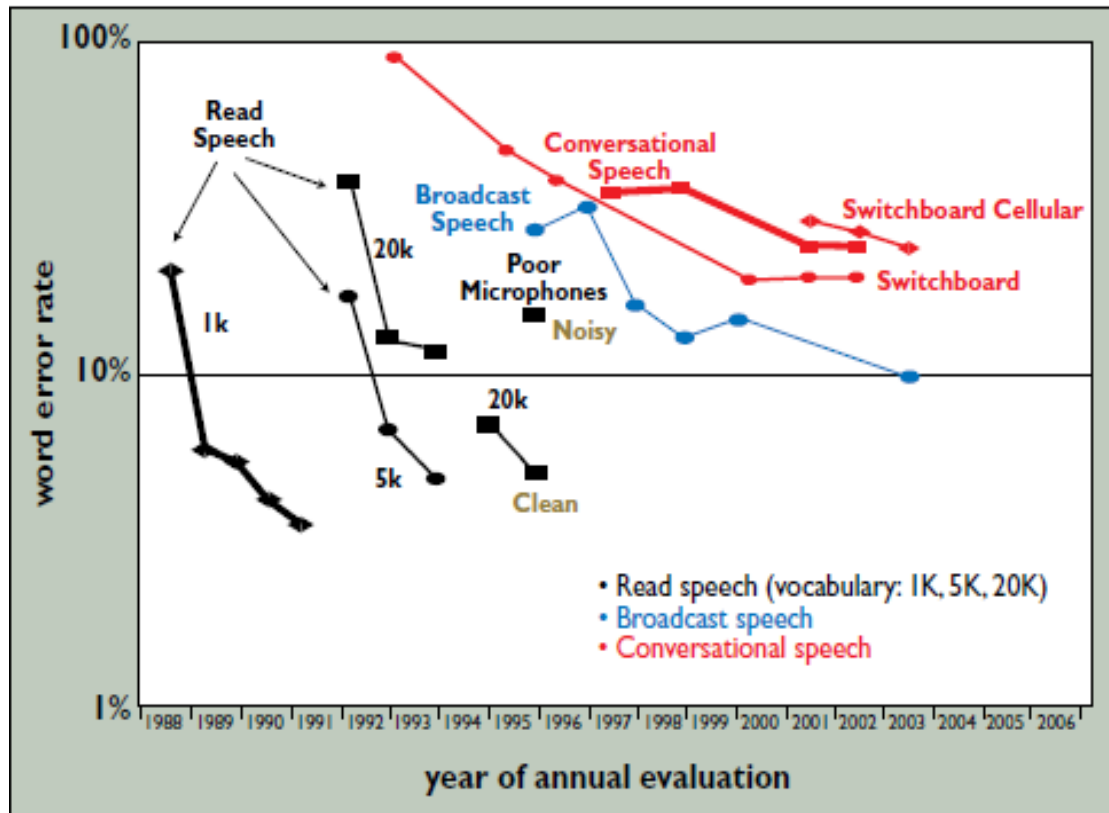


Figure 2 Historical Progress on Word Error Rate [4]

In figure 2 above, we see that between 1988 and 1989 when read speech vocabulary was 1k, the word error rate was more than 10% but with passage of time until 1991, with the same vocabulary size, the word error rate considerably dropped below 10%. Also we see that the accuracy of SR decreased initially when the vocabulary size increased for e.g. between 1992 and 1993 when vocabulary size for read speech increased to 20k, the word error rate increased significantly above 10%. Finally we see, despite advancement of SR capability to 'Conversational speech' from 1998 onwards, the word error rate maintains above 10%.

However, word error rate (WER) as a measure of performance is quantitative in nature and only works when it comes to check accuracy of the transcriptions, they don't consider the usability aspect of ASR system. This limitation is mentioned by McCowan et al [5] stating it is not easily interpretable in terms of application usability.

Deng and Huang [4] identifies two great challenges in ASR system today, the first one is to make it more environmentally robust by increasing robustness to noise and other sources such as echo distortions and channel distortions, to address this problem "Aurora" an experimental framework had been developed to evaluate the performance of speech recognition systems in noisy environments, it consists of noisy speech database against which training is done [4] [6]. The study shows the speech recognition performance increases with cleanliness of the input signal. This is also in line with the results of the study, see section 5.3.2.

The second challenge is of spontaneous speech recognition which means to enable casual speech with SR systems just as with humans converse [4] which makes it very difficult for ASR systems to accurately detect hence new techniques such as flexible acoustic modeling, sentence boundary detection etc are being worked on to overcome this challenge [7].

Juang and Furui [8] addresses state-of-the-art in automatic speech recognition in two ways, one is the size of vocabulary and the other is the speaking style.

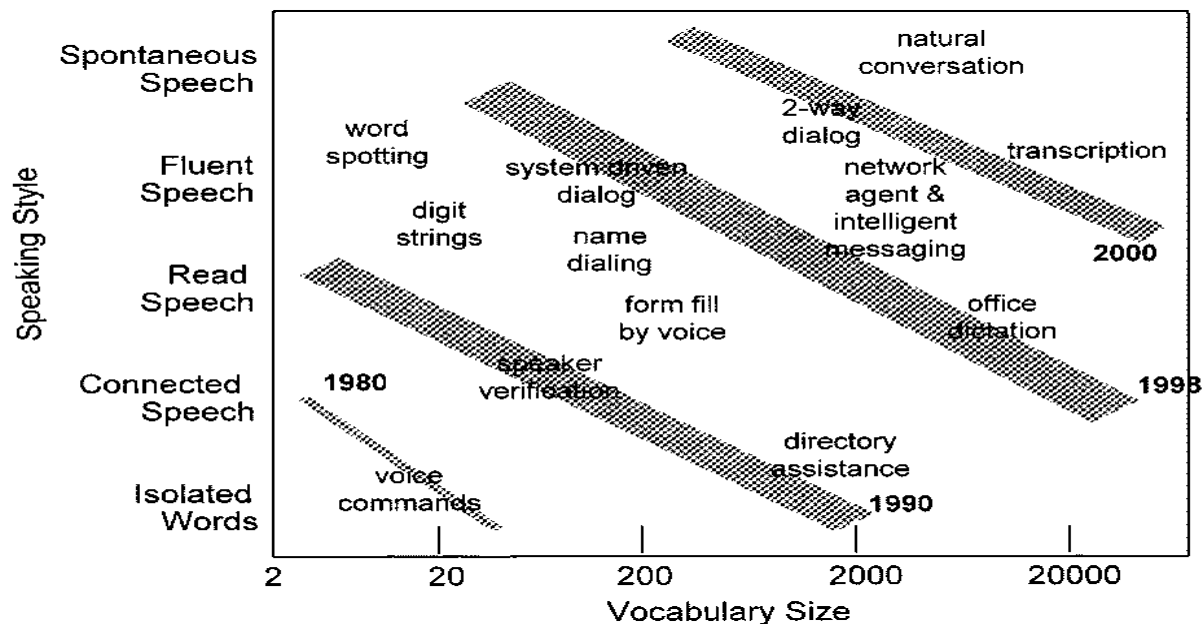


Figure 3 Progress in Spoken Language Technology [9]

Figure 3 above shows when in 1980, the vocabulary size was 20, only 'Isolated words and Connected Speech' in form of voice commands was possible. Finally by 21st century, the state of the art improved to a vocabulary size of 20k with a 'Spontaneous and Fluent speech' speaking style with widespread commercial applications of spoken language processing from transcription softwares to 2-way dialog systems.

Today, state of the art speech recognition applications enable free-style speech with increased vocabulary size and adaptive acoustic model, below are examples for state of the art implementations.

[2] [3]

- Airline companies having voice based conversational agents guiding travellers for making reservations.

- Google's Chrome has a voice search feature that allows users to use voice to search information⁴.
- ASR systems in cars to assist drivers to manipulate navigational and entertainment systems inside car.
- Telephony applications based on interactive voice response systems used in businesses to assist users e.g AT&T universal card services which asks the user to speak card number.
- Dictation based applications assisting users to write big amounts of text by only speaking into the system, example of these include IBM's *ViaVoice*⁵, *Dragon's Naturally Speaking*⁶.
- Automobile applications such as Clarion's AutoPC which enables drivers to access information while driving
- Apple's SIRI⁷ which allows user to give instructions via voice.

However, despite great accomplishments in this area, poor speech quality which is due to low environmental robustness (noise, echo cancellation and channel distortions) of Automated Speech Recognition systems is a major factor in low accuracy of SR systems when placed in real-world speech [3].

Huerta [10], in his doctoral dissertation focuses on transmission of error free mobile network speech recognition, he analyzes the working of coding technique known as GSM codec for speech signals that aims at reducing redundancy in the speech signal. He shows that speech coding is a source of distortion in the speech signal as well. He identifies sources of degradation in a mobile ASR environment as speech coding and error in transmission, he further describes tradeoffs/limitation of a mobile ASR solution under three different types of mode of operations which according to him are **Mobile Network Speech Recognition** where recognizer lies at remote server location which means distorted speech signal due to transmission channel variability but large powerful central servers, **Mobile Terminal Speech Recognition** where speech signal does not need to travel on transmission channel but is processed at the user side but then this put more pressure on memory and computing resources on terminal and finally **Distributed Speech Recognition** where ASR computational resources are distributed between terminals and ASR central servers but it requires standardized front-end [10].

Vikki et al [11] investigated and identified technical challenges involved in creating a speech recognition system for mobile communication due to globalization and proposed a multilingual

⁴ http://en.wikipedia.org/wiki/Google_Voice_Search

⁵ <http://www-01.ibm.com/software/pervasive/viavoice.html>

⁶ <http://www.nuance.com/dragon/index.htm>

⁷ <http://www.apple.com/ios/siri/>

ASR architecture which according to them would consists of three key units: automatic language identification, on-line pronunciation modeling and multilingual acoustic modeling modules.

Similarly from a usability perspective, Toth and Nemet [12] identify the issues involved in creating multimodal interface for speech input/output for mobile phones having different platform which according them are lack of standard speech APIs coupled with limited memory and computing resources on different platforms. They suggest an XML based language for describing multimodal SUIs (Speech User Interfaces) which can run on different platforms. Currently we see two dominant mobile platforms i.e. Apple's iOS and Google's Android which have their own standard for speech interfaces.

Koo et al [13] in their work have proposed another way of implementing ASR for portable devices to minimize the challenges such as choosing of appropriate ASR algorithm. They propose in their statement "free-running speech recognition software which does not need to push the button before saying voice command and is always running for detecting key-words under real environment" [13]. They suggest filtering modeling techniques and utterance verification methods and have implemented the ASR software on a PDA with these techniques which according to them "propose free-running speech recognition software which does not need to push the button before saying voice command and is always running for detecting key-words under real environment" [13].

3. Case Study – A Voice Recognition Approach

An exploratory case study was conducted with Volvo Information Technology AB⁸. The study consisted of investigating problems in case creation at Volvo, prototyping an Automatic Speech Recognition solution on a mobile platform for noisy workshop environment and finally summarizing the feedback from evaluation by end users.

The research question addressed by this study is:

- What are the reasons of poor quality Argus cases?
- How can quality of Argus cases be improved with a Smartphone based ASR solution?
- What are the challenges in adopting a smartphone based ASR solution for creating Argus cases?

3.1. Research Structure

A qualitative research approach that is described as interpretive paradigm by Hennink et al [14] was used for this study to understand problems while creating cases by technicians in *Argus* system. Figure 4 below shows the Hutter-Hennink Qualitative Research Cycle adopted for this study.

⁸ www.volvokit.com

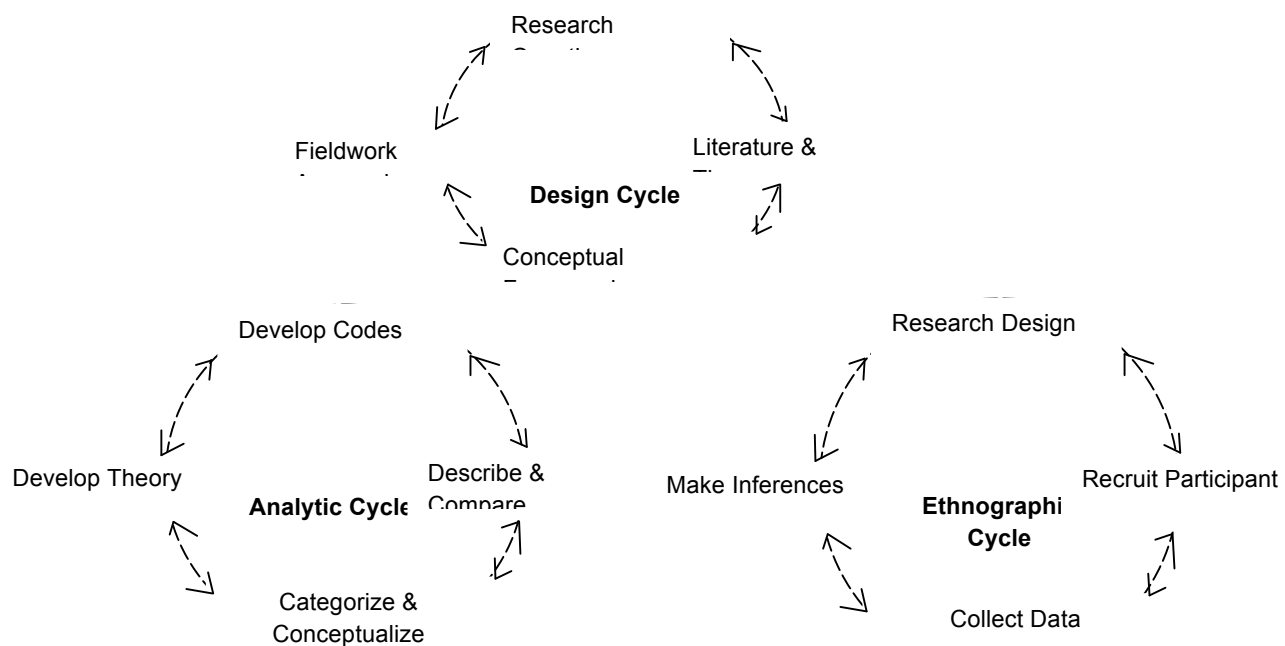


Figure 4 Hutter-Hennink Qualitative Research Cycle [14]

Figure 4 above shows the research starts in the design cycle i.e. first identifying the question that needs to be answered in context of the study along with the literature review of the work done before in similar situations to gain better understanding of the overlapping areas of the problem. During this a conceptual framework is established guiding the study. The lists of tasks are not waterfall in nature and the research question is refined more & more as the understanding of the problem increases.

The planning and design of the study occurs in the ethnographic cycle, it includes tasks such as identifying the correct participants/populations under study, data collection and inferences from the data. The activities in these tasks can be switched back n forth and can run in parallel.

The final phase of the study is linking up all the pieces of evidence, this is done in the analytic cycle which begins by assigning codes to the data collected, the codes are pieces of words pointing to piece of evidence later to be used for analysis, these can be either inductive or deductive i.e. the code can be either directly from the data known as inductive code or can be deduced from the data known as deductive code.

Once the coding is done, they are assigned to categories based on common theme and finally theme in different categories is linked together to develop a theory i.e. to give holistic picture of the problem.

3.2. Study Context

3.2.1. Argus - Case Management System

Volvo Group⁹ uses a web-based case reporting system known as **Argus** to create cases. Volvo dealers use it to seek support from Volvo Technical Service. The system has a number of support functions but for the purpose of our study we only focused on functions relating to creating and managing cases.

Figure 5 shows snapshot of an *Argus* case.

The screenshot displays the Volvo Argus Case Management System interface within a Microsoft Internet Explorer browser window. The page title is "eService - Microsoft Internet Explorer". The interface includes a navigation bar with "Home" and "Preferences" tabs, and a "Help Log In/Out" link. The main content area is titled "Details:" and contains several sections:

- Service Request**: This section displays case details for SR # 1-1133751886. It includes fields for Area, Contact Name (SAMANTHA WORRALL), Dealer (VOLVO GROUP UK LIMITED), Dealer Id (GB000001), Chassis Series (A), Chassis #, VIII/Serial # (YV2ASS0C06A04811), Model (FH13 62T), and Function Group (3811-combined instrument, complete). It also shows Caller Name, Call Back # (+01926414416), Opened date (8/31/2007 01:38:59 PM), and Closed status.
- Service Request Description**: This section contains a text description: "Sometimes the dash does not show the AdBlue level. We have check the tank level and sender which both look ok. There are no error codes."
- More Info**: This section displays "Km / Hr / Mi: 100000 Km" and "Tot. Diag Time Appr:".
- Updates**: This section includes an "Add Update" button and a table with columns for "Comments", "Type", and "Created". It shows "No Records".
- Attachments**: This section includes an "Add Attachment" button and a table with columns for "Attachment Name", "Comments", "File Type", "Size", and "Created". It also shows "No Records".

Figure 5 An Argus Case¹⁰

An Argus case is a service request raised by technicians in the dealer workshop if they need assistance from technical support team to solve the problem using Argus system. The case consists of the following mandatory input that needs to be filled in by the technicians:

⁹ <http://www.volvo.com>

¹⁰ Snapshot taken from Argus Dealer Training Presentation at Volvo

- Fault description
- Function group number
- Summary
- Job card
- Milage

The fault description includes when, what and how the problem happened, what actions were taken to solve it, this can include a photo or drawing as well for e.g. “*Trucks experiencing dreading due to faulty SCR work*”. Function group (FG) number identifies the problem area in which the problem falls e.g. FG 2 relates to problem with engine. Summary is a short description of the problem for e.g. “*D7E320 - Coolant leakage at cylinder head*”. Job card contains information about the vehicle and “Milage” shows the status of the vehicle.

3.2.2. Argus Case Creation Process

Figure 6 shows the Argus case creation process. It starts when the customer comes in with the problem vehicle. The receptionist creates a job card based on information given by the customer and then forwards it to the technician. The technician based on the information in the job card diagnosis the problem in the vehicle and if required raises a service request (Argus case) for technical support in Argus system.

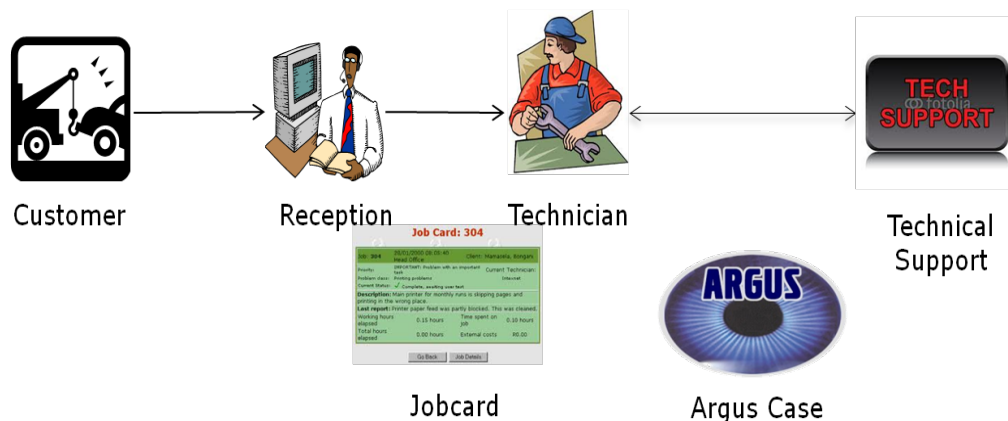


Figure 6 Argus Case Flow

3.3. Problem Background

At Volvo dealer's workshops, the technicians on ground ask for technical support if required by creating a case using *Argus* system. Currently creating a case in *Argus* is time consuming for technicians with less computer skills while some find it hard to express their words in writing to describe vehicle problem using keyboard. This leads to poor case creation with insufficient problem description hence the Volvo technical support again need to refer the case back to the technicians to get more information in order to solve it which increases customer service time.

Based on the problem above, Volvo IT decided to explore/evaluate ASR as an option to create better Argus cases and hence reduce customer service time.

3.4. Study Aims and Objectives

The study aims to understand the problems with reporting an Argus case and evaluate to which extent an ASR approach can resolve the reported issues. The objective is to build an ASR prototype and have a workshop evaluation to see how it reflects on the reported issues i.e. pros and cons of using an ASR approach.

3.5. Study Scope

For the purpose of this study, scope included English (UK) speaking native Volvo dealers in the UK, first and second line support teams from Ghent (Belgium) and Gothenburg (Sweden) respectively. The scope of activities included interviewing/observing the workshop dealers located in the UK and interviews with support teams from Ghent and Gothenburg respectively.

Further it consisted of developing an ASR prototype in Android with English (UK) as an input language, ASR prototype evaluation by native English (UK) speaking dealers and finally summarizing their experience.

3.6. Study Design and Planning

3.6.1. Study Population

The composition of study participants included one workshop technician from Volvo dealer workshop in UK, two-second line support from VTS Gothenburg, Sweden and two first line support from VTS Ghent, Belgium were referred to us for interview purpose by Volvo IT. The number of persons for interview was determined by the principle of saturation as described by Glaser and Strauss [15] as a point where information starts to repeat itself.

The goal was to get technicians that can be interviewed in English having sufficient experience in creating cases in Argus along with back-office support (first line and second line) who evaluate the quality of the cases created.

3.6.2. Data Collection

In context of our study, three types of sources were used to collect data:

- 1) Interviews
- 2) Observations
- 3) Workshop

According to Seaman [16], interviews are useful technique to collect opinion and impression about something, in our case it was effective technique to get experiences of *Argus* stakeholders creating and managing service requests. Also combined with observations which according to Mack et al [17] it is aimed at learning perspectives held by the study population proved helpful in understanding the workshop environment. Finally workshops were conducted at the end of ASR prototype evaluation to understand user experience. The details of these methods are given in subsequent sections.

3.6.3. Interviews

To investigate the research question, a semi-structured interview guide was developed with open-ended questions. There were two sets of questions that were developed, the first set of questions were intended to capture the issues faced by Volvo Technical Support team with *Argus* cases and the second set dealt with questions addressing problems faced by Volvo technicians in workshops while creating *Argus* cases.

The interview guide was revised as more information gathered about the problem domain that helped to refine the questions. A total of 5 in-depth semi-structured interviews were conducted containing a mix of open and closed questions. Two interviews were one-to-one with VTS second line support in their respective offices in Gothenburg, Sweden, two telephonic interviews with VTS first line support situated in Belgium and UK respectively and one was a telephonic interview with UK based Volvo dealer.

The telephonic interviews were conducted, as physical interviews were not possible considering the geographical limitations. The purpose of interview was explained to each of the participant to establish a rapport as suggested by Hennink et al [14].

The language of all interviews was English and each interview consisted of about 40-60 minutes on average. Also all interviews were digitally recorded using a Smart phone with prior permission from the participants.

Field notes were made during the course of interview and shortly after each interview, it was transcribed and all data relating to identity of the participant was anonymized to maintain the anonymity. See Appendix A for interview guide.

3.6.4. Observations

There were two observations conducted, one was on May 31, 2012 between 1300 and 1500 hrs at the Volvo Dealer workshop located in Borås, Sweden servicing bus and trucks. This workshop according to the workshop manager was the 5th largest in Sweden. The purpose of the visit was to have noise assessment of the workshop and observe working style of technicians.

The second observation took place during the ASR prototype evaluation in Volvo dealer workshop on August 9th, 2012 in Guildford, England dealing with bus and trucks.

During the observations, noise levels were recorded near various noise source to understand the noise environment, also importantly the working style of the people in different roles and the physical construction of workshop were important part of the observation. See Appendix B for account of both the observations. Figure 7 shows layout of the Borås facility.



Figure 7 Volvo Dealer workshop located in Borås city in Västra Götaland

3.6.5. Workshop

A workshop was conducted to understand the user experience after ASR prototype evaluation. The workshop was an hour's discussion among the users of the ASR prototype. The detail of the workshop is given in section 6.2.

3.6.6. Ethical Concerns

Anonymity of the interviewees was maintained while transcribing. All participating individuals were informed about the type and objective of the research being conducted. Also prior permission of the participants were sought to record the interviews and later focus group discussion as well. Finally, observations at the workshops were sought and approved.

3.7.Data Analysis Methodology

Once the data collection was complete, the following methodology was adopted for analysis of data as suggested by Hennink et al [14] in the analytic cycle in Figure 4.

3.7.1. Code Development, Cross Case Comparison and Categorization

The transcript text from the interview was broken down into meaningful codes, each piece of text that had relevance was assigned a code either as an inductive or deductive type. See Appendix C for excerpt of codebook.

Soon after the code development, each of the different codes as suggested by Hennink et al [14] were compared across the data set in the transcript to get different perspectives on a single issue. Once the comparison was complete, codes that belonged to similar pattern were merged into one category to get the holistic view of the underlying issue.

3.7.2. Conceptualization, Theory Development and Verification

Once the categories of the issues were identified, links between the categories were analyzed and a common pattern was identified among them enabling conceptual understanding of the data as a whole. Finally theory was developed based on the conceptualization done earlier.

Theory developed was verified by checking how well it is grounded in the data as suggested by Hennink et al [14] consistency checks were applied to ensure traceability back to the data.

3.7.3. Data Quality and Study Limitations

The data collected was only from the one native English (UK) speaking dealer, two first line and two second line English (UK) speaking support persons from UK, Belgium and Sweden respectively. Hence the outcomes of the research cannot be applied to the all the dealers in Volvo Dealership Network.

Similarly, the characteristics of the dealer workshops can also be not generalized to all dealer workshops. However, the data collected gives a snapshot of the problems and challenges in the context of the study conducted.

4. Prototype Experiment

Once data analysis was complete, a possible to solution to enhance the case description quality was a mobile-based ASR prototype for dealers. For the context of this study, a prototype was developed for English (UK) speaking Volvo dealers in UK. The prototype consisted of two fields where a technician can select text field one by one and speak the case description in these fields respectively in their default environment. See figure 9.

The prototype was developed on Android¹¹ mobile platform and was based on the client-server architecture, where the “FreeSpeech” application was a client connected with Google speech servers for processing speech data and getting text results. Figure 9 shows the ASR prototype developed named as “FreeSpeech”.

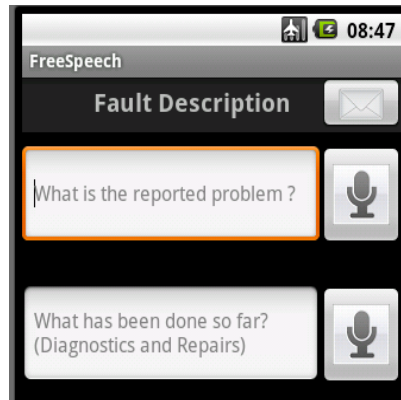


Figure 8 FreeSpeech – ASR Prototype

The developed prototype and user manual can be downloaded from the link:

<https://www.dropbox.com/s/y39sdvbcpkhp9nk/ArgusFreeSpeech.apk>

https://www.dropbox.com/s/tz04uk74a4t1893/Argus_FreeSpeech_User_Manual.pdf

4.1. Preparation

The available mobile based online speech solutions development kits were android speech API¹², Dragon Mobile SDK¹³ that provides 90 days free trial use and iSpeech Mobile SDK¹⁴. The online speech solution takes audio data as input and returns text. For the purpose of prototype android speech API was selected as it was open source and had much larger acoustic and language model in the Google managed backend servers compared to other, which were commercial.

Today, there is not yet available offline speech solution for mobiles, which can be deployed on mobile platform because of its limited memory and processing constraints.

However, the available offline speech solution such CMU Sphinx¹⁵ for standalone machines can be tailor designed for a mobile platform but it can then only hold limited acoustic and language model. ZTE¹⁶ Smartphone was used an android device for deploying the prototype.

¹¹ <http://www.android.com/>

¹² <http://developer.android.com/reference/android/speech/package-summary.html>

¹³ <http://www.nuance.co.uk/for-developers/dragon-mobile-sdk/index.htm>

¹⁴ <https://www.ispeech.org/developers>

¹⁵ <http://cmusphinx.sourceforge.net/>

¹⁶ http://www.zte.com.cn/en/press_center/news/201011/t20101108_194339.html

A user manual was also developed along with the prototype to assist technicians in familiarizing themselves with the prototype.

4.2. Evaluation

On August 9th, 2012, the FreeSpeech prototype was evaluated at Volvo dealer workshop in Guildford, England dealing with bus and trucks. The evaluation was carried out with the Shift Supervisor, and two technicians. All three persons were native English speakers in their 30s. The aim was to get different user experiences. The technicians had no prior experience of using Argus while the shift supervisor was an experienced person in creating cases in Argus.

The evaluation environment was not as loud as it could be during the late afternoon or the evening session when the repairs are done. Prior to the evaluation, an introductory session was held explaining the purpose of the evaluation and the methodology of the evaluation.

For the purpose of evaluation ZTE android phones were used with the prototype installed on it, along with their headsets as well. These devices were connected with the workshops wifi.

Each of the participants was asked to take one vehicle problem among list of given vehicle problem and speak case description in to the FreeSpeech application in the workshop conditions.

The participants were also provided with user manuals so they can familiarize themselves with the application. The cases used for evaluation were taken from previous Argus cases and were as below:

- Vehicle is reported to have black smoke whilst pulling
- Near side headlight not working
- AD blue mid 128 PC 45890

Each of the users spent on average around 10 minutes and they separated from each other while testing the application, truck engine was started at the place to induce maximum distortions.

During the testing the users were interrupted by other persons in the workshop for their daily routine matters, however they repeated the evaluation incase of breakup during the evaluation.

Once the evaluation was done, a workshop was conducted to get feedback on the prototype and experience of the participants using speech for creating case description, the results sections show the inferences from the workshop.

5. Results

The results presented here are categorized into results from interviews, observation and from the workshop.

5.1. Interviews

This is a filtered list of results that contain only those which fall within context of ASR. A complete list of the result has been presented to Volvo IT.

5.1.1. Less User Friendly Argus GUI

This was a deductive inference where one of the reasons for less case description input was found to be Argus GUI, as it had less features such as absence of search function to find similar cases, absence of icons and signs that can assist user and the huge set of complex information which is not encouraging for technicians to give more information. This fact is stated by for instance by one second line support person A as: "You can make the system quite easily handling use icons and signs".

At another occasion one of the second line support person B stated: "The biggest problem with this system is complexity of the system and the system is static".

5.1.2. Missing Information

This was a deductive inference where it appeared to be a communication gap between what support persons thought the case should have as must information and the what technicians thought is sufficient for case creation. Also lack of standardization for describing what a case should and should not have is also one of the reasons of information gap in the service request descriptions. This fact is stated by one of the second line support person A as: "There some fields which are not mandatory to fill in, so if they fill in some information and not fill the other fields they can still send the case further without filling in basic information that we need fault description, functional group, summary, job card, fault code and mileage".

At another one occasion second line support person B stated: "...when they have programation issue we really need certain things they don't give for e.g. the client ID, the PC they are working on, what version of factual is installed on it, the error codes they receive and what they were doing when they were programming".

5.1.3. Less Expressiveness

This was a deductive inference where the ability to express a situation into words directly impacts the richness of case description, this was one of the problems where technicians with lesser expressive capabilities found it difficult to sufficiently write case descriptions, for them it is

easier to speak than to write, also the level varies from person to person based on their education level & the type of market, for instance this was stated by one first line support person A as: "Once again is really big difference, you have some mechanics which are really quick with all the applications while other ones working long times there, it's really difficult for them, its dependent on the market you are working on, I know in Europe they are quick in adapting to new systems".

One of the technicians A stated when it comes to writing versus speaking as: "it depends how you can express what is in your mind into words, it is generally easier to speak than to write".

Another technician B when inquired the same stated: "...it's just getting the words in your mind into descriptive form".

5.2. Observations

5.2.1. Noise Levels

Location	Source	Noise level (dB)
Computer room	Human conversation, extraneous noise	57.4 (Avg of 5 recordings)
Service and Repair Area	Engine cleaner, grinding area	68 (Avg of 4 recordings)
Service and Repair Area	Computers on high rise table inside workshop	54

Table 1 Noise Levels at Workshop

During my visit I recorded some noise level near various sources in the workshop, Table 1 shows the noise levels of the distortion. These recording were taken in a close range (5- 10 meters) from the source in a comparatively quieter conditions than usual business days as mentioned by workshop manager which suggests the noise level may rise to 120 dB during the first shift. See Appendix B.

5.2.2. Busy Hands & Mobility

During the observation of the workshops, the technicians in the workshop had busy hands i.e. their hands were either greasy or had repairing tools in the hand.

Also the technicians had desktop systems in computer room where they had to go if they needed to create cases in Argus, at most there would be some fixed desktop systems placed outside the computer room at random places to save time in going to and from the computer room, this was found to be inconvenient for the technicians as they had to move away from the vehicle to log the problem and also time consuming hence resulting in lesser case description.

The technicians used other IT systems such as “TechTool” on laptop near the problem source i.e. trucks when diagnosing, the need for mobility for creating cases in Argus as stated by one dealer A is: “...so if there is an option to create a case from iPad that would be really useful because you can have the information at the vehicle sometime and check against what you got on vehicle”.

The observation is also complimented by the fact that the technicians mostly diagnosed the problem outside the bay area unless the vehicle was required for repair to be inside, at this point they had laptop on a trolley which they took out and it was connected to the vehicle. Also the inspecting of the vehicle was also outside the bay area.

5.3. Prototype Workshop

5.3.1. Education/Training Vs. Ability to Express

The technician found it very hard to express themselves. Table 2 shows the speech to text conversion using FreeSpeech prototype in workshop environment by technicians and shift supervisor for case scenarios presented during the evaluation.

Case Scenario	Person	Test Questions	Speech to Text Conversion
Vehicle is reported to have black smoke whilst pulling	Technician	What is the reported problem	Hello
		What has been done so far ?	[...]
Edblue mid 128 PC 45890	Shift supervisor	What is the reported problem	active airblue phone with android voice in holbeach road livermore old sewing 12 line for sushi on iphone 1 who are you no more 1 ball pool
		What has been done so far ?	supergroup 13 I'm sorry canada is sealed systems post oak are you dancing correct amount into work tricia I remove universal theme park so sorensen chicken so I care
Near side headlight not working	Technician	What is the reported problem	hey but not work headlight on pesticides not working
		What has been done so far ?	no power at light note power at cats

Table 2 Speech to Text Conversion using FreeSpeech

Table 2 above reflects a technician having little education/training did the first scenario with very little description compared to the shift supervisor having more education/training.

5.3.2. ASR Accuracy

Table 2 shows poor speech to text accuracy during prototype workshop where the noise levels reached upto 120 dB. This result also conforms to Aurora study [6] which shows that the word accuracy will increase as the cleanliness of the input signal increases.

5.3.3. Interactive Voice Based Wizard

The users during the discussion session were critical about two things in particular:-

- Talking to a software without a response
- Larger Screen Size

Firstly, they preferred to talk to someone on the phone to get instant feedback as one said "Better to talk to human to explain stuff". Their idea was based on using *TechTool* application (used within Volvo group) that guided them through the process so an interactive voice response system was something they thought could workout.

Also during the discussion session one of the user commented it would be useful if you also had live support with guiding you while speaking to the ASR. The users at the workshop suggested to instead have a voice based troubleshooting system that will assist them in solving their problem rather than waiting for them to speak up the case description.

Also, the participants had mostly iPhones so they were used to it, so when ZTE phones with small screens were given to them they felt uncomfortable.

5.3.4. Company Phones Vs. Private Phones

However, despite the convenience of an mobile based ASR solution, the participants during the discussion session after evaluation pointed that they usually place their phones in the box while at work hence they are not willing to use their phones if there is such an application as it might make their phone vulnerable to damage during work although if the company provided them with phone they would look into it.

5.3.5. Diagnostic Solution Vs. ASR Solution

During the workshop, one of the technicians suggested if instead there could be an application which can connect with the vehicle and then get the fault codes and send it as case. This would

mean increase in the richness of the case description. Also during the workshop session, the manager stressed on *Argus* to also have built in spells checking capabilities as well.

5.3.6. Technological Constraints & 3rd Party Solution

To be able to work for any online speech based application, the network has to be a good one so there are very minimum network latency issues which could obstruct with smooth functioning else as time is precious they would prefer to file a case traditionally even if the quality is not good.

During the prototype evaluation, the wifi network was interrupted frequently which means it puts more demand on the technological surrounding for an online speech solution to work seamlessly.

Also another point of consideration is to see the tradeoff between streaming through 3rd party solution such as Google in our case and the confidentiality of the data.

6. Theory/Interpretation

Based on the results from the previous section, an interactive voice response system with a rich yet simplified ASR interface can overcome the problems of less user friendly *Argus* GUI, missing information and less expressiveness. An interactive ASR system would be guiding the user to input required information step by step hence enabling in providing complete, precise and required information.

As in the observations, the technicians hands were busy with the tools & they had to be moving around, a mobile-based ASR solution will cater the needs of mobility but also will provide the technicians with an alternative to input case with minimum hand interaction during busy hands situation.

Also an ASR solution with diagnostic capability will boost *Argus* case quality. During the workshop session, the technicians indicated to prefer the ASR with diagnostic capabilities where the solution would get the fault codes combined with their description of the problem.

However, the noise levels in the workshop with up to 120 dB during first shift will affect the accuracy of ASR hence there still will be the need to edit the speech to text translations.

7. Conclusion & Discussions

In this study, the results showed that the possibility of using mobile-based ASR to improve *Argus* case descriptions is **not possible** currently in context of the study. The failure can be seen from two perspectives, one is the usability aspect & the other is the ASR accuracy. From a usability aspect, during the prototype evaluation workshop, participants felt like talking to a wall.

They would instead prefer to talk to someone on the phone to get live support. The participants suggested that they preferred diagnostic software that would get all the fault codes from the vehicle and compile a case description with their minimal input to the case. Also the idea of expecting the technicians to express themselves using free speech depends on the expressive ability of the person and training in case reporting. Hence the use of interactive voice based ASR interface coupled with multimodal interfaces can be a step forward to resolve usability issues. Interestingly Toth and Nemet [12] also suggest the use of multimodal interfaces to enhance the user experience.

Secondly, the speech recognition technology today in a noisy environment is not mature enough to support free speech. Section 4.3.1 shows the ASR accuracy during the prototype evaluation. However,

Koo et al [13] in their work have proposed a free-running speech software looking for key-words under real environment” [13]. In their approach they reject out-of-vocabularies (OOV) [13]. It might appear free-speech is accurately possible under real environment but in our case we are not detecting keywords & not rejecting any vocabularies.

Finally, future works in this direction involves a two-pronged approach. One is to focus on the user experience such as interactive voice based ASRs and multimodal interfaces which can also possibly integrate with external systems to retrieve fault codes. Also by creating awareness about best practices for creating cases in Argus will lead to increased quality. Second approach involves to enhance the ASR accuracy, a language model can be developed or could be subset of a bigger language model that contains the common words and expression used while creating cases but then also the decision to have the language model online or offline would need to be considered, in case of an online language model, the network bandwidth should be sufficient whereas in case of an offline one, the memory/processing needs of the target device which in our case can be any portable device such as mobile phones or table PCs would have to be considered. But the key to accuracy would be the maturity of ASR technologies which are sufficiently noise redundant to support free speech.

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Appendix A – Interview Guide

Introduction

This interview guide serve as a data collection tool for capturing technician's problems with Argus and how could a voice based approach via a mobile can facilitate/enhance their usability.

The research questions are divided in to two parts, one set of questions deal with the support personnel while the other set deals with technicians on the ground.

Support Questions

1) Please describe yourself, your role ?

Probe:- Since how much time you have been in this role ?

2) Describe your typical workday ?

3) What is Argus ?

Probe:- How do you interact with it ?

Probe:- What is the most important activity performed with Argus ? and why ?

4) What is a case ?

Probe:- What are the types of case ?

Probe:- What information is contained in the case ?

Probe:- What are the mandatory/important information required ?

5) Can you describe case-support process workflow?

6) How often do you receive support requests ?

Probe:- What is the average case processing time ?

Probe:- In what different languages do you deal with case requests ?

7) What problems do you face with case reports?

Probe:-Please describe ?

Probe:- Which is the most commonly occurring problem and is also important ?

8) How do you rate the quality of data received ?

Probe:- If bad ? why ? what is missing ? why is missing ?

9) Are you satisfied with the accuracy of information delivered in case report?

Probe:- If not, why ?

10) How do you get over with the above mentioned problem ?

Probe:- Do you call the dealer ? or is there another way ?

11) Do you envision some solution to overcome such problems ?

Probe:- Elaborate ?

Probe:- How it can reduce customer service time ?

Dealer Questions

1) Please describe yourself, your role ?

Probe:- Since how much time you have been in this role ?

2) Describe your typical workday ?

3) What is your native language ?

Probe:- How is your English language proficiency ?

4) Can you please describe your work environment ?

Probe:- How are working hours divided ? Shifts ?

Probe:- Can one person work in another shifts?

Probe:- How many people are there in a shift ?

Probe:- What native languages and how is their English language proficiency and age groups?

Probe:- How is one shift different from another ?

4) Are there different types of dealerships ?

Probe:- If so, please elaborate the difference ?

5) What type of vehicles do you service ?

Probe:- Bus ? Truck ?

6) How would you rate the noise Levels in different shifts ?

Probe:- Why is it different ?

Probe:- What is the source behind it ?

7) Do you also use noise as a diagnostic method ?

Probe:- Why and what ways do you use it ?

8) What is Argus ?

Probe:- How do you interact with it ?

Probe:- What is the most important activity performed with Argus ? and why ?

9) What is a case ?

Probe:- What are the types of case ?

Probe:- What information is contained in the case ?

Probe:- What are the mandatory/important information required ?

Probe:- What information do you fill in ?

Probe:- What is the important piece of information ?

Probe:- How often do you encounter a case?

Probe:- How much time does it take to fill out a case ?Which part takes most of the time ?

10) What is the most difficult part in creating a case or do you face difficulty in creating a case ?

Probe:- Why ?

Probe:- How do you get over it ?

11) Can you describe case-support process workflow?

12) Are you satisfied with usage of Argus system ?

Probe:- If not, what/why problems do you face ?

Probe:- If yes, how ?

13) Are you satisfied in creating a case currently ?

Probe:- If not, why ?

Probe:- If yes, how ?

14) How would you rate your computer skills?

15) Do you use Smartphone ?

Probe:- Which vendor ?

16) Do you envision a solution to facilitate case creation ?

Probe:- Elaborate ?How would it facilitate ?

Appendix B – Observations

Observation 1

The observation took place on May 31, 2005 between 1300 and 1500 hrs at the Volvo Dealer workshop located in Borås city in Västra Götaland servicing bus and trucks. This workshop according to the workshop manager was the 5th largest in Sweden. The purpose of the visit was to have noise assessment of the workshop and observe working style of technicians.

I was observing the place by walking through the workshop space accompanied by the workshop manager who guided me through the area.

Location- Facilities & Layout

The workshop had a front office or the reception area for greeting the customers equipped with office furniture which included a reception table with desktop systems, adjacent to front office was a store which has different vehicle related tools for technicians.

Attached to the front office on the backside is a large vehicle servicing and repairing area for damaged/accident vehicles. It consists of 14 bays whose dimensions are 24x26x5. Furthermore, it is a sheet metal workshop with high roof ceiling supported by beams. It has industrial sectional doors made of galvanized steel sheet which is present at the front and rear of each bay. It remains closed unless the bus or trucks are required to move in.

The ceiling of the workshop has electrical wires hanging from the top which appeared to be extension wires, the workshop has vehicle repairing tools attached to boards which was placed in between spaces in the workshop and machines which included hydraulic machines, engine cleaner and bus lifters etc.

The place also had a computer room which had IT systems, this was within the workshop but distinctly separated by glass walls where the noise level was 50% less in comparison to outside. It was in this place where the technicians created service requests in Argus however as coming to and from the computer room was frustrating for them, they had also 3 computers placed outside in the workshop on high rise table to facilitate technicians for case reporting.

People and Activities

There were two types of people working, the first type was technicians/mechanics which were in shirts and pajamas carrying various toolsets tied to their pajamas, these were involved in

vehicle repairing/servicing activities such as waxing and polishing the vehicles, mending the vehicle parts, welding etc. Other type of people were white collar personal which were in the reception area and small office cabins, these were workshop managers.

Noise Environment

According to the workshop manager, August is really peak period for them when even it is hard for them to walk in between spaces with a lot of noise i.e. before the snow and during September – October, the workload is low.

On our visit, there was only a bus that was being repaired, there were two types of noises according to my observation, ambient noise which included background noises, the ones I observed were workers vehicle engine starting, listening to radio, waxing/polishing, noise from hydraulic machines, engine cleaner, nut loosening machine.

The other type of noise is the impulsive one i.e. generated from the use of tools, these included the banging of hammer, mending of vehicle parts, tool trolley, moving of drums.

Also the workshop manager told that they prefer to do the major repairing cases within the first shift that lasts till 1600 hrs and minor cases of repairing are done in

Also when I inquired from the workshop manager about noise management, he replied the ceiling might have some sort of noise absorption but on the whole it did not have any noise proofing procedures, also owing to the fact that this workshop was located along the side the road and away from the residential area.

Noise Levels

Location	Source	Noise level (dB)
Computer room	Human conversation, extraneous noise	57.4 (Avg of 5 recordings)
Service and Repair Area	Engine cleaner, grinding area	68 (Avg of 4 recordings)
Service and Repair Area	Computers on high rise table inside workshop	54

Table 3 Noise Levels at Workshop

During my visit I recorded some noise level near various sources, Table 3 shows the noise levels of the distortions. These recording were taken in a close range (5- 10 meters) from the source in a comparatively quieter conditions than usual business days as mentioned by workshop manager which suggests the noise level may rise to 120 dB during the first shift.

Observation 2

This observation was carried out during the ASR prototype in Volvo dealer workshop on August 9th, 2012 in Guildford, England dealing with bus and trucks. The Regional Technical Manager, Workshop Manager, Shift Supervisor along with technicians during the evaluation, accompanied me.

Location- Facilities & Layout

The workshop consisted of reception area, computer room with IT systems, warehouse and service/repair area which consisted of Techo Bay, Service Bay and MOT bay.

Furthermore, it was a sheet metal workshop with high roof ceiling supported by beams. It had industrial sectional doors made of galvanized steel sheet at the front only. The ceiling had air pipes suspended from it along with electrical wiring.

The workshop had Techo, Service and MOT bay which had no partition in between them but they were separated from the computer room and reception area.

The inside of the bays was surrounded by toolboxes, damaged trucks, trolleys with techtools laptop, lifts, big blue cans, steel cupboard, radio etc.

Also to mention, all trucks were parked outside the bays area and were moved in the bay when required.

People and Activities

The workshop was divided among the administrative staff and the technical people. The administrative people were seated inside the reception area building fairly well dressed this including the Workshop and Regional Technical Manager as well. The technicians and the shift supervisor were dressed in blue kits with tools along their side and hands filled with grease and oil.

The observed activities during the day included inspecting the trucks outside bays for problem, test driving by the workshop manager, checking the stats of the problem vehicle by the shift supervisor using the tech tool on trolley and plugging the wires into the truck.

It consisted of technicians checking the problem of the vehicle by running the engine & using air pipes. Also it was the shift supervisor using the tech tool with the truck.

Noise Environment

The observation was made from 0800 till 1200 hrs which according to RTM¹⁷ is fairly quieter part of the day where service mostly takes place, it is late afternoon and evening when repairing work is carried out and the sound levels are higher.

¹⁷ Regional Technical Manager

On our visit, there were only a bus that was being repaired, there were two types of noises according to my observation, ambient noise which included background noises, the ones I observed were workers vehicle engine starting, listening to radio, waxing/polishing, noise from hydraulic machines, air pipes, engine cleaner.

The other type of noise is the impulsive one i.e. generated from the use of tools, these included the banging of hammer, mending of vehicle parts, tool trolley, moving of drums.

Noise Level

Table 4 shows measurements that have been taken near to the different sources of distortion.

Source	Noise level (dB)
Airpipe	75
Engine Running	73
Radio Source	66
Computer Room	60

Table 4 Noise Level at Workshop

Appendix C – Code Book

Code	Description	Interview Text	Person	Thick Description
FG	Function Group	“Product specialist and we have divided the car to nine different function groups, and I am in group function 3 with telematics and system dynafleet”	SL	The second line support has adopts structured approach and each one belongs to a function group to solve a case hence creating domain experts.
		“And here there are different function groups and all the people work here are product specialist, product specialist in dynafleet, product specialist in engine, and chessie and engine are different separate function group. For example if you work with engine you will work in function group 2.”		
ML	Multi-Language	“If they cannot solve it they send it to our place as a 2 nd line support. We have customers all over the Europe more less over the world as well, so they are translate the case because they are Multilanguage and they know more or less language and they also use Google translate for certain things.”	SL	The FL is responsible for case translation to English and assigning the proper severity level to the case for action by support people.
		“Then I answered back to the dealer in their family language. We are working in the Situation that all of us speak English and there are a lot of nationality so, some people are speaking Italian, eastern language. I am working in the first place for Russia, Poland, Check republic and also in English spoken dealers. We are also working with priorities. For example if I got cases in my monitor and we have three severities level , critical, high or medium so if there will be lots of critical English cases, then I will try to solve them in first step”	FL	

SP	Search Problem	"In the case that I want to help my colleague who is in the vacation and he called and said I have case three weeks ago maybe you can try to find that one and it is the problem. But when we need to help each other or if the case handled six months ago and you don't remember all the details. You can search manually and you can make some query in the system but it is not that much easier. We have tested the version of searching which is a tool not in Argus but it is out of Argus, which is searching in Argus data base and that worked quite good I think but we want to have it built in."	SL	There are already exists similar cases in the Argus database but finding them is problematic as there is no case search feature within Argus to find similar cases. Its more of a usability problem.
Mal	Mandatory Information	"There some fields which are not mandatory to fill in, so if they fill in some information and not fill the other fields they can still send the case further without filling in basic information that we need."	SL	Different view on mandatory information depends from case to case but the Fault Description, FG, Summary, Jobcard, FaultCode, Mileage are considered to be mandatory across all cases contrary to dealer perspective of having brief description of problem and cust details.
		"Fault Description, FG, Summary, Jobcard, FaultCode, Mileage,"		
		"That depends on the type of question we get, for e.g when they have programming issue we really certain things they don't give us for e.g the client ID, the PC they are working on, what version of factual is installed on it , the error codes they receive, and what they were doing when they were programming." "Vehicle info and from a technicians point of view brief description of what is problem with the vehicle and cust	FL D SL	